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Potato Flakes of Increased Density

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ABSTRACT

A process is described whereby a dehydrated mashed potato product of high bulk density can be prepared from potato flakes by mechanically manipulating the hydrated flakes at or below the moisture range at which granulation occurs.

This report is based on work done at the

EASTERN UTILIZATION RESEARCH AND DEVELOPMENT DIVISION

Philadelphia 18, Pa.

POTATO FLAKES V

POTATO FLAKES OF INCREASED DENSITY

BY

Roderick K. Eskew,* Fred H. Drazga,**
James Cording, Jr.,*** John F. Sullivan,**
and C. F. Woodward****

INTRODUCTION

It is estimated that more than 180 million pounds of dehydrated mashed potatoes will be produced from the 1960 harvest. Somewhat more than half will probably be in the form of granules, a product having a density of about 56 pounds per cubic foot and thus suited for military and institutional use. The remainder will be potato flakes, a product recently developed at the Eastern Utilization Research and Development Division of the Agricultural Research Service, U.S.D.A., in Philadelphia and now being widely produced commercially. Approximately 25 million pounds of flakes were produced from the 1958 crop in 8 plants located in 5 States. Twelve flake plants are now in operation with a combined annual capacity of about 62 million pounds. Potato flakes are also being made in Canada, England, Australia and Germany.

When flakes are cut or broken into pieces, typically about 1/2 inch square, their bulk density is about 14 pounds per cubic foot. This bulk density gives a package well-suited to the retail and institutional markets, but the product, because of its bulk, may be disadvantageous for military use under field conditions. This can be reduced to some extent by cutting flakes in a hammermill equipped with sharp

* Chief, Engineering and Development Laboratory
** Chemical Engineer, Engineering and Development Laboratory
*** Head, Plant Products Engineering Investigations, Engineering and Development Laboratory
**** Chief, Plant Products Laboratory

knives and a screen having 1/8-inch diameter holes. This increases the density to about 25 pounds per cubic foot. Such cutting can be done without any impairment in quality if, in the process of making the flakes, high-solids potatoes are used, precooking and cooling prior to cooking are properly carried out and an emulsifier* such as glycerol monopalmitate or glycerol monostearate is incorporated in sufficient amount. Finer cutting, however, may impair texture of the reconstituted mash through excessive comminution of cell walls and loss of desirable body.

Pursuant to current work at the Eastern Utilization Research and Development Division on further reducing the bulk of potato flakes to better adapt them to military use, a process has been developed for mechanically manipulating them in a moist state to give products of high density. This information is timely because the production of regular potato flakes and flakes of high density can be advantageously combined.

A brief summary of the conventional flake and granule processes as now carried out industrially is given below.

MANUFACTURE OF POTATO FLAKES

The potato flake process has been described in a number of publications (1,2,3,4,5,6,7).** It entails peeling and trimming potatoes in any conventional manner followed by slicing them into 1/2-inch slabs. These are precooked in hot water for about 20 minutes at 160° F. This gelatinizes the starch and enables subsequent mashing of the cooked potatoes with minimum

* Individual manufacturers should consult the Food and Drug Administration, Washington 25, D. C., and the food and drug officials of the individual States involved, to determine if the use of any proposed additive is permissible, and if so, what limitations are placed on its use.

** Figures in parentheses refer to the Literature Cited at end of this publication.

cell damage. After precooking, the slices are cooled to 75° F. or lower for at least 20 minutes. This retrogrades the soluble amylose so that pastiness does not result from any cell breakage that may occur in processing. The slabs are then cooked from 30 to 50 minutes in atmospheric steam until soft enough to rice, the varieties with lower solids generally requiring the longer cooking time. Additives are incorporated into the riced material. These generally include preservatives such as sulfur dioxide and antioxidants. Another additive important in the process is a monoglyceride such as glycerol monopalmitate or monostearate. This ties up any soluble starch that may not have been retrograded and enables the production of a flake of good hot-water tolerance, texture, and steam-table life. Because of the precooking and cooling steps and the use of a monoglyceride, potato flakes of good flavor and possessing the desirable properties mentioned above can be made from a wide variety of potatoes from different growing areas.

CONVENTIONAL GRANULE PROCESS

Much literature on the manufacture of potato granules has been published. The Department of Agriculture at its Western Utilization Research and Development Division has carried out extensive research resulting in a better understanding of the functions of each step in the process and facilitating the commercial production of a quality product (8,9,10,11,12).

The granule process varies somewhat among manufacturers. It employs the basic principle of incorporating dried granules into freshly prepared mash to obtain a moisture of about 37 percent. This is mixed, cooled, conditioned, and mixed again. Some starch retrogradation takes place and the mixture is granulated to a free-flowing mixture of individual cells and cell aggregates. This is dried in air-lift and fluidized bed driers to produce a high-density product consisting substantially of individual potato cells.

A characteristic of the granule process is the necessity for adding back dried granules to fresh mash to obtain the moisture level (about 37 percent) at

which granulation will occur, requiring the continuous recycling to the process of about 85 percent of the potato solids. Such recycling complicates quality control and repeatedly exposes a portion of the product to the rigors of drying. Although much research has been done to eliminate recycling of "add back" in the granule process, none of the methods is currently in commercial use.

POTATO FLAKES OF HIGH DENSITY

A marked increase in the density of potato flakes may be accomplished by hydrating them to a moisture range between about 25 and 45 percent and manipulating them mechanically to give a gentle rubbing action. This has been done batchwise in the pilot plant using a Hobart* planetary mixer operating at approximately 100 r.p.m. A similar result should occur from the lifting and tumbling action produced by ribbon or pug mill type mixers.

The hydration can be accomplished by adding the flakes in the proper proportions to freshly cooked potatoes with or without prior ricing or mashing; or a fine spray of water may be used. The former is more economical as it entails the removal of less water per pound of product. The object is to equilibrate the mixture as quickly as possible so that the formation of balls is avoided. Incorporation of a monoglyceride, such as glycerol monostearate, to the cooked potatoes or mash before adding the flakes induces crumbling and tends to prevent formation of balls. This should be used as an emulsion in an amount to obtain about 1 percent on the basis of the potato solids in the moist mixture, including the amount of glycerol monopalmitate used in making the flakes. A method for preparing the emulsion is given on page 13. Cooling the fresh potato component to below about 80° F. has also been found advantageous in this regard.

* References to particular products or companies does not imply their endorsement by the U.S. Department of Agriculture over others not mentioned.

Flakelets (Small Flakes of High Density)

The moisture to which the flakes are hydrated during the manipulation has a marked effect on the bulk density, screen analysis and appearance of the finished product. If, for example, regular 1/2-inch flakes of commerce are ground through a hammermill equipped with sharp knives and a screen having 1/2-inch diameter holes, the bulk density will be about 25 pounds per cubic foot--too bulky for some purposes. But if these flakes are mixed with previously cooked, cooled, sliced potatoes in proportions to give an average moisture of about 26 to 32 percent, and are sufficiently manipulated in a Hobart mixer, they can be dried to a product having a bulk density of between about 40 and 52 pounds per cubic foot. This will consist principally of small flakes or flakelets, some partly laminated, and interspersed with flake fragments and a few individual potato cells and cell clusters. The reduction in average size will have been accomplished principally by separation rather than by fragmentation of the cells. The latter would have predominated had a comparable increase in bulk density been accomplished by merely grinding unhydrated flakes.

In general, over 95 percent of the finished product will pass a 12-mesh screen and can be easily reconstituted to mashed potatoes of good flavor and texture. The very small fraction not passing this mesh may be ground for potato flour or meal. Alternatively a coarse sieving of the moist mixture may be done, and the few balls so removed can be added to the fresh cooked potato component of succeeding batches. But if manipulation has been properly carried out, the mash should be substantially free from such balls.

The exact percent moisture and the time of mixing to be used will be governed by the type of potatoes employed, the extent to which the flake appearance is to be retained, and the bulk density desired. The following example illustrates the product resulting from a specific set of conditions: The flake component was made by the conventional process using Cali-

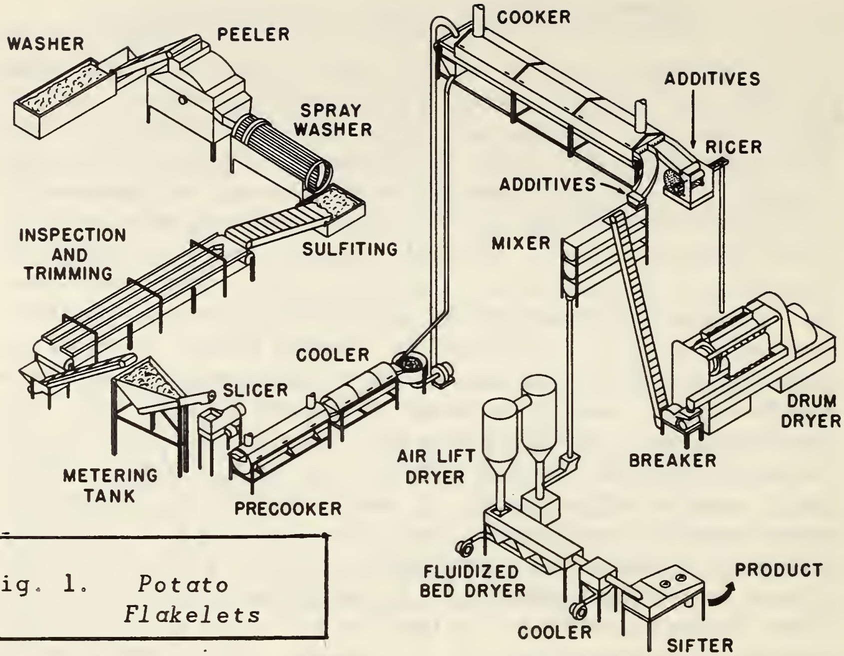

Fig. 1. *Potato Flakelets*

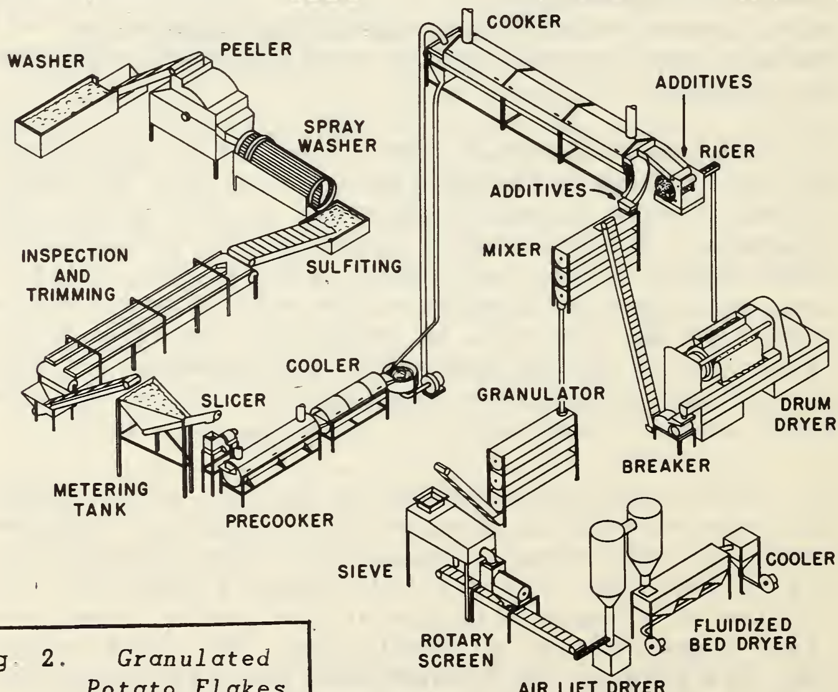

Fig. 2. *Granulated Potato Flakes*

fornia White Rose potatoes to which was added 0.7 percent glycerol monostearate before drying. The flakes contained 5 percent moisture and were ground through 1/8-inch diameter holes, using a hammermill. Their bulk density was 25 pounds per cubic foot. The cooked potato component was cooled to about 80° F. and the ground flakes were added in the proportion to give a mixture of 31 percent moisture. This was mixed for 20 minutes in the uncovered bowl of a Hobart mixer. After drying to 15 percent moisture in an air-lift drier followed by fluidized bed drying, the product had a bulk density of 50 pounds per cubic foot. Ninety-eight percent passed through a 12-mesh screen and could be rehydrated with hot water and milk to a mash of good texture, flavor, and color.

The preparation of flakelets in this way provides a means of preserving the desirable attributes of flakes and at the same time gives the advantages of increased bulk density. Among these are better adaptation to military use and lower packaging and shipping costs. Packaging in inert gas becomes economically feasible, thus enabling the use of reduced amounts of antioxidants. The incorporation of additives such as dry milk and butter flavor can be conveniently accomplished a few minutes before terminating the manipulating cycle. Such a product would require only hot water and seasoning on reconstitution.

Pilot-plant research is continuing in order to determine the optimum combination of initial flake size, hydration moisture, and mixing time for important potato varieties. Figure 1 shows how potato-flake operations could be slightly modified to produce flakelets, i.e., dehydrated mashed potatoes of high bulk density possessing the appearance of very small flakes.

Granulated Flakes

Where the utmost in bulk density is required, e.g., 56 to 57 pounds per cubic foot, the flakes may be hydrated to a moisture range where cell separation, i.e., granulation, occurs readily and flake identity is lost. In general this range will be between about

36 and 45 percent. For economy in operation hydration would be accomplished by adding flakes to cooked potatoes. Although the process entails such addition to obtain a granular form, it differs from the conventional granule process for in the latter, dried product is repeatedly recycled so that each granule passes through the mixing and drying cycles, on the average, 7 times. In contrast, in making granulated flakes the dried product goes completely out of the system after passing only once through the mixing and granule drying steps. No portion of the product is ever subjected to any drying conditions more than twice, and the first stage is always the very rapid (about 10 seconds) drum drying.

The conditions described below are satisfactory if granulation is not to be carried to completion and separation of granulated from incompletely granulated material is to be done by sieving of the moist product. A rather low moisture (36 to 40 percent) is desirable for such a situation. The bulk density of the product may be less than if granulation were done in a moisture range of 42 to 45 percent. The latter range is more advantageous if some other method of separation, such as air classification, is used instead of sieving, or if a longer time is allowed for complete granulation.

Equilibration

As shown in Figure 2, a small portion of the slices from the cooker are diverted to mixing with flakes. The slices and flakes are combined in proportions to give an average moisture of 36 to 40 percent, taking into consideration any water that will be introduced with the additives. These figures represent the moistures actually found by analysis of the mixture after 3 minutes' agitation in a closed container. To obtain these values under our conditions of operation required combining the flakes and slabs in proportions calculated to give 38 to 42 percent. These differences were consistent and were due to loss of moisture during handling. The figures for mix moistures used hereafter are those actually found by analysis after 3 minutes' mixing in a closed container.

Equilibration of moisture between the wet and dry components is a prerequisite for good granulation. Although both moisture diffusion and granulation occur to some extent simultaneously, the conditions most favorable to one may inhibit the other. They are therefore considered as separate steps. The function of the equilibration step is solely to distribute the additives uniformly and to assure that each particle of potato reaches the critical moisture level for subsequent easy cell separation. Moisture loss and unnecessary cooling should thus be avoided during equilibration. Moisture diffusion does not require constant mixing. Thus after an initial mixing period for distribution of ingredients, the mass may, if desired, be allowed to remain quiescent during some of the equilibration period. The total time for equilibration will depend on moisture, temperature, type of mixer used, flake density, and other factors. In general, it should be less than for conventional granules. Thirty minutes was found to be adequate in pilot-plant tests. Except for an initial 3-minute mixing and 30-second stirrings every 10 minutes, the mass remained stationary in a covered container for a 30-minute period. Less than this time may have been sufficient.

Although flakes may be used such as those that are currently made commercially, with a bulk density between about 14 and 20 pounds per cubic foot (depending on size), it is preferable to prepare flakes of low bulk density if they are to be used for granulation. These can advantageously be made either by using a double-drum drier, or preferably by operating a single-drum drier at higher speeds than used in making the higher-density flakes of commerce. A single drum operated at 4 r.p.m. instead of 2 r.p.m. will give a sheet with a density of about 1.65 pounds per 100 square feet instead of 2.25 pounds per 100 square feet. These are typical values obtained when using potatoes of about 20 percent solids. The relationship between drum speed, solids content of potatoes, sheet density, final moisture, and product output has been studied by Cording, et *al*. (4) Besides favoring equilibration, use of the less dense

sheet increases drum drier capacity by 65 percent or more, depending on sheet moisture.

The flake component should be ground to a fineness not to impair texture of the reconstituted product, but small enough to accelerate moisture equilibration. Flakes should not be ground finer than to pass 1/8-inch diameter holes. Flakes which are to be added to the mash need not be reduced to 5-6 percent moisture as would be the case if designed for direct sale. Drying only to 10-15 percent will increase the output of the drum and lessen the heat effect of drying.

Additives

A monoglyceride such as glycerol monopalmitate or glycerol monostearate should be added to the mash which is to be drum dried to prepare the flake component. This is usually done on the ricer. The amount to be added will vary with the solids content of the potatoes; but for the high-solids types best suited for granulated flakes (e.g., 21-23 percent) it should be between 0.4 and 0.5 percent on the basis of the solids in the mash. If more than this amount were used with high-solids varieties the mash would be cottony and would not adhere to the drum. In making either dense flakelets or granulated flakes, additional monoglyceride should be added to bring the total amount to 1 percent on the basis of the potato solids present. This should be added as an emulsion (prepared as described below) and mixed into the cooked potato component before the flakes are added.

In commercial potato-flake manufacture, an antioxidant such as Tenox IV is usually incorporated with the monoglyceride emulsion to give, on the basis of solids in the mash, the equivalent of about 200 p.p.m. of butylated hydroxy anisole and butylated hydroxy toluene. Of the amount added, only about 50 p.p.m. remain in the product. *These amounts are beyond those currently cleared by the Food and Drug Administration and should not be used after March 1, 1961, without prior approval.* At this level the flavor of flakes is

preserved for about 6 months if air packed and 1 year if nitrogen packed. No storage tests have been made on granulated potato flakes, but their keeping properties can reasonably be assumed to be similar to those of flakes at the same moisture level.

A method for preparing the emulsion of monoglyceride and antioxidant, recommended by the manufacturer of the former is quoted below:

"The following procedure was found satisfactory for incorporating Myverol Types 18-00, 18-02 and 18-07 in a solution for 1,000 pounds of mashed potatoes (0.5 percent in finished flakes):

1. 9,000 milliliters water heated to 144° F. (start stirrer).

2. 500 grams Myverol (remove heat source when viscous dispersion is evident).

3. 75 grams Tenox VI or 37.5 grams Tenox IV. (Cool to 135-130° F. before adding).

4. 200 grams nonfat dry skim milk.

"Continue stirring until temperature reaches 120° F. or below. Can be cooled to 35° F. if preferred. Solution should be stirred while using. Do not reheat above 120° F.

"The maximum temperatures suggested in making the solution are quite critical as the addition of Tenox VI or IV will cause the Myverol (distilled monoglycerides) to gel if the temperature is more than 3 or 4 degrees above the maximum recommended. However, the water-Myverol dispersion can be as high as 160° F. for Myverol Types 18-00, 18-02 and 18-07 so long as the temperature is reduced when Tenox is added. After the water-Myverol dispersion is complete, the temperature can drop 10 degrees before adding Tenox, with the only difficulty being increased viscosity. The Tenox immediately reduces the viscosity. Investigation of the Tenox shows that butylated hydroxy anisole or butylated hydroxy toluene used at the same level as in Tenox

IV or VI would cause gelling when added to the water-Myverol dispersions if the temperature was elevated. Slight gelling will occur at the maximum temperatures recommended if the stirrer is stopped. Once the solution is cooled to avoid possible gelling, it should not be reheated above 120° F. for Myverol Types 18-00, 18-02, and 18-07.

"The elimination of the Waring blendor helps the foam problem as with less agitation the foam is held to a minimum.

"The addition of Myverol before adding the Tenox results in quick dispersion of the Tenox. The Tenox in turn helps control the additional foaming that normally occurs when nonfat dry skim milk is added to the solution."

Potato flakes usually contain between 150 and 250 p.p.m. of SO_2. This results from adding to each 100 pounds of mash, 89 milliliters of a solution comprising 25 grams $NaHSO_3$, 75 grams Na_2SO_3, and 900 milliliters water. Since dense flakelets and granulated flakes are given a further drying, additional sulfite solution may have to be added in the mixer so that the finished product contains 200 p.p.m.--the amount reported (17) to be required in commercial granules to retard browning.

Granulation

The phenomenon of granulation or separation of the mixture into a free-flowing "sand" of individual cells is accomplished by gentle mixing and the lapse of time. Since it is accelerated by reducing both temperature and moisture below that best for the initial equilibration, it can desirably be carried out in separate equipment. The type of ribbon mixer employed in the conventional granule process may serve the purpose. Air circulation over the mixture will accelerate granulation by evaporation and cooling. Moreover, some loss of moisture during granulation will greatly facilitate subsequent sieving of the moist mixture.

Just what happens that causes cell separation during granulation is not fully understood. In the conventional granule process (where starch insolubilization may not have been done by precooking followed by cooling and the use of a monoglyceride), starch retrogradation is an important factor in obtaining a free-flowing granular state. In granulating flakes, however, the starch has already been retrograded. Thus full equilibration of moisture is probably the most important factor--coupled of course with the rubbing action incident to mixing and some moisture loss.

Using a Hobart planetary mixer with 80-quart bowl and paddle rotating at about 100 r.p.m., granulation was sufficiently complete for sieving in 30 minutes. Granulation was in an open container with air circulation, resulting in a moisture drop of about 3 percent.

The mixer used was ill-suited for inducing complete granulation. In the final stages it was more prone to form balls than to disintegrate them. Thus, it is not feasible to predict from these batch operations in the pilot plant exactly what mixing and holding times are optimum for large-scale continuous operation. Those skilled in the art of conventional granule manufacture should not find flake granulation difficult.

It should be noted that since no product is recycled to the mixing, granulating, and air-lift drying operations, the capacity of these equipment items can be less than about 1/6 that required in the conventional add-back process.

Obviously for the process to be practical, dried product must be substantially all suitable for "pack out"; none should be recycled. This is theoretically possible if the mixers and granulators achieve a positive and intimate contact between the wet and dry components and afford sufficient retention time. However, practical considerations dictate that some insurance against less than "perfect" granulation be provided. Thus sieving or air classification of the

granulated mixture is recommended, with subsequent size-reduction of the "overs."

Sieving

Pilot-plant experiments have shown that the granulated mixture can be sieved through 20-mesh (openings 0.033 inch) using a vibrating screen of the Ro-Ball type. If the moisture does not exceed about 34 percent, little difficulty with blinding of the sieve openings should occur. The "overs" from the sieve consist of small balls, generally less than about 1/8 inch in diameter and clusters of cells not quite friable enough to separate during sieving. This fraction is passed through a rotary screen with positive action to reduce it to the desired size as discussed later.

The proportion of "overs" from sieving will, of course, depend on the effectiveness of granulation, the moisture of the mix being sieved, and on sieve efficiency. The effectiveness of granulation and hence the proportion of "overs" obtainable in continuous commercial operation cannot be dependably predicted from batch studies in the pilot plant.

Air Classification

As an alternative to sieving, incompletely granulated material may be effectively separated from the moist mixture by air classification. If the moist material is fed into a duct carrying a vertical stream of air at about 800-1000 feet per minute, the fully granulated fraction can be collected overhead by means of a cyclone separator and receiver, while large pieces, requiring screening for reduction to smaller size, fall from the bottom of the duct. This method of separation is preferable to sieving if the moisture level used for granulation is above about 40 percent. For example, the finished product resulting from granulating at 42 percent moisture would have a very high bulk density--a desirable feature, yet it would be impractical to sieve the material while still in the moist state. Air classification of the moist granulated mixture is the indicated alternative.

Screening

The material not passing through the 20-mesh sieve, or accumulated at the bottom of the air classifier must be reduced to substantially individual cells. This can be done by forcing it through a cylindrical screen having perforations about 0.023 inch in diameter. This was conveniently accomplished in the pilot plant using a paddle-type finisher. Spring steel wiper blades were attached to the paddle edges adjusted so that the blades gently wiped the inner screen surface. This operated satisfactorily; no plugging of the holes was observed. However, some slight cell damage resulted from the abrasive action of the metal wipers. This did not significantly impair the texture of the reconstituted product. It could probably be avoided by the use of equipment better suited to the purpose, for example, a brush sieve.

This tolerance for cell breakage in granulated flakes stems largely from the starch-retrograding treatments previously described. For example it has been shown (18) that potato flakes made by the use of such treatments can tolerate as high as about 25 percent broken cells before texture is impaired. Should impairment manifest itself, it would be as a pudding-like consistency in the reconstituted mash and not as pastiness. No soluble starch is present to contribute the latter property.

The screened product is continually combined with that sieved through 20-mesh (or collected as "overhead" from the air classifier), the combination being fed to an air-lift drier.

Drying

Drying can be done in the same mannerused for conventional granules, i.e., by air-lift and fluidized bed driers. In pilot-plant operation the combined sieved and screened fractions were dried in one pass in an air-lift drier at 350° F. to about 15 percent moisture. They were finished to 6 percent moisture in either a fluidized bed or tray drier.

Product

Granulated flakes made by the procedures described above have the following typical screen analysis:

U.S. Sieve #	30	35	50	70	100
Cumulative % passing	99.9	99.1	89.6	82.3	68.2

Although the bulk density of the granulated flakes (56 pounds per cubic foot) is the same as that of conventional granules, the screen analysis is somewhat different. Fifteen to twenty percent may be retained on 50 mesh. Practically all of this fraction, however, will pass 30 mesh. This coarser fraction is not objectionable in granulated flakes for the particles have not become case-hardened through repeated recycling. Hence they reconstitute to a non-grainy mash both at boiling temperature and at the more temperate conditions resulting from mixing one part cold milk with three parts boiling water.

CONCLUSION

The increase of the bulk density of potato flakes provides a basis for more extensive use where low density poses a problem, such as in military field operations. The denser product facilitates incorporation of dry milk solids, enabling reconstitution with hot water only. It also reduces the cost of packaging making feasible the use of an inert gas pack and reduced amounts of antioxidant.

The increased density is achieved without the disadvantages of recycling of add-back. The operations lend themselves to integration with the production of potato flakes by conventional methods.

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